

Childhood Asthma

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Asthma prevalence in children has increased 58% since 1980. Mortality has increased by 78%. The burden of the disease is most acute in urban areas and racial/ethnic minority populations. Hospitalization and morbidity rates for nonwhites are more than twice those for whites. Asthma is characterized by recurrent wheezing, breathlessness, chest tightness, and coughing. Research in the past decade has revealed the importance of inflammation of the airways in asthma and clinical treatment to reduce chronic inflammation. Asthma is associated with production of IgE to common environmental allergens including house dust mite, animal dander, cockroach, fungal spores, and pollens. Some interventions to reduce symptoms through control of dust mite and animal dander have had positive results. Control of symptoms through interventions to reduce exposures to cockroach antigen has not been reported. Studies illustrating causal effects between outdoor air pollution and asthma prevalence are scant. Increases in asthma prevalence have occurred at the same time as general improvements in air quality. However, air quality appears to exacerbate symptoms in the child who already has the disease. Decreased pulmonary function has been associated with exposure to particulates and bronchial hyperresponsiveness to smoke, SO₂ and NO₂. Symptoms have been correlated with increased levels of respirable particulates, ozone, and SO₂. Interventions that reduce the negative outcomes in asthma associated with outdoor environmental factors have not been reported. Control of asthma in children will entail the collaborative efforts of patients, family, clinical professionals, and school personnel, as well as community-wide environmental control measures and conducive national and local policies based on sound research. **Key words:** asthma control, child health, childhood asthma, environmental precipitants. — *Environ Health Perspect* 107(suppl 3):421–429 (1999). <http://ehpnet1.niehs.nih.gov/docs/1999/suppl-3/421-429clark/abstract.html>

Prevalence, Diagnosis, Treatment, and Precipitants of Asthma

Prevalence of Asthma in Children

In the past 20 years significant increases in pediatric asthma have been noted in this country and worldwide. Asthma is the most common chronic disease of childhood in the developed world, affecting approximately 10 million children in the United States under 16 years of age (1). Between 1982 and 1992, the prevalence rate for pediatric asthma (under 18 years of age) in the United States increased by 58%. The mortality rate from asthma for persons 19 years of age and under increased by 78% from 1980 to 1993.

Activity limitation and the use of health services for asthma are significant. In 1994 there were 169,000 hospital discharges for the disease among children under 15 years of age, a rate of almost 30 per 10,000 population. Statistics for 1996 show that although asthma was the 10th most common principal diagnosis in emergency department visits among all patients, asthma led in emergency department visits for children, excluding accidents (2). In

1995 there were 9 million physician office visits for asthma in the United States and a significant number of these represented pediatric visits. The proportion of people with asthma who have activity limitation rose from just over 19% in 1988 to 22% in 1994. Again, children accounted for a significant portion of this limited activity (2).

The costs associated with health care use and disability attributed to asthma are high. Direct medical expenditures for all patients with asthma amounted to \$3.64 billion in 1990, and indirect economic losses accounted for an additional \$2.6 billion (2). These indirect costs include such factors as days missed from work or school, caregiver expenditures, travel and waiting time, and premature mortality.

Asthma is particularly troublesome in urban populations (1) and racial/ethnic minority populations (3). In the United States, the asthma hospitalization and morbidity rates for nonwhites are more than twice those for whites. The activity limitation rate is higher in African Americans; about 30% of African Americans with asthma have restricted activity because of their disease. The causes of increased morbidity and the differential risk for urban,

racial/ethnic minority populations are not well understood (4). It is hypothesized that increased rates are likely due to multiple factors such as high levels of exposure to environmental pollutants including tobacco smoke and environmental allergens, lack of access to medical care, and lack of financial resources and social support to manage the disease effectively on a long-term basis (2).

There are also costs of asthma related to the social and psychological domains of childhood. Data suggest that children's school absences and school performance are affected by the disease (5,6), although greater absenteeism than the general population has not been demonstrated (7). Some observers have noted that psychological adjustment (e.g., self-esteem) of children with asthma is inferior to children without the disease (5,6), but this opinion has received limited empirical study and is questioned (8). There is little doubt that the condition often restricts recreation, play, and related forms of physical activity and its management can be a source of contention and disruption within families (9).

The Diagnosis of Asthma

Asthma is defined as "a chronic inflammatory disorder of the airways in which many cells and cellular elements play a role...in susceptible individuals, this inflammation causes recurrent episodes of wheezing, breathlessness, chest tightness, and coughing,

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particularly at night or in the early morning. These episodes are usually associated with widespread but variable airflow obstruction that is often reversible either spontaneously or with treatment. The inflammation also causes an associated increase in the existing bronchial hyperresponsiveness to a variety of stimuli" (10). Asthma usually begins in childhood, often in association with an inherited susceptibility to produce IgE to common environmental allergens, including house dust mite, animal protein, fungal spores, and pollens (11). It is estimated that up to 80% of children with asthma may be atopic. A range of other precipitants, discussed below, is associated with symptoms of asthma. The key indicators for considering a diagnosis of asthma are a history of cough, particularly if it worsens at night; recurrent wheezing; recurrent difficulty in breathing; or recurrent chest tightness (12). Although asthma cannot be cured, it can be controlled by a combination of pharmacologic and nonpharmacologic means.

Accurate diagnosis of asthma is complex, and it is believed that the disease continues to be underdiagnosed and undertreated (13). In recognition of this fact, the National Asthma Education and Prevention Program (NAEPP) was established by the National Institutes of Health in 1989 to enable professionals, patients, and communities to manage the condition more effectively. The expert panel guidelines promulgated by the NAEPP (10) have become the basis for clinical practice in the United States and an adaptation provided by an international working group (Global Initiative on Asthma) serves as the basis for clinical practice outside the United States (14).

Asthma Treatment

Paradoxically, although asthma prevalence has reached alarmingly high rates over recent years, therapies for pharmacologic treatment of asthma have also advanced dramatically. Important in enhancing treatment has been the recognition of the central role of inflammation in the disease. Continuous use of anti-inflammatory medicine to combat this underlying factor and use of bronchodilators to reduce constriction of the bronchial tubes during exacerbations are considered to be the frontline treatment for the disease for patients over 5 years of age with persistent symptoms.

The number of patients who actually receive anti-inflammatory prescriptions from their physicians is thought to be small

compared to what is indicated. In low-income communities this gap between the need for and use of anti-inflammatory medicine is even greater. For example, a recently conducted study of 597 children with asthma in grades 2–5, attending 15 schools in Detroit, Michigan, classified their disease severity according to NAEPP expert panel guidelines (10). Just over 20% of children with both moderate persistent and severe persistent asthma were receiving anti-inflammatory therapy. Guidelines would suggest that virtually all of these children should be on controller medicine. Recent efforts by the NAEPP and professional societies of clinicians have focused on increasing practitioners' use of anti-inflammatory medicine for patients with asthma.

Causes of Asthma Symptoms

Two factors appear to predominate in contributing to asthma episodes: colds and viral respiratory infections. Asthma is associated with perennial and seasonal rhinitis and sinusitis (10), and research has shown that the resulting inflammation of the upper airway influences lower airway hyperresponsiveness and symptoms (15–17). Another important contributing factor to asthma symptoms is exercise. A number of patients will only experience asthma symptoms when physically active. For others, exercise as well as other precipitants may induce symptoms. Food and food additives (e.g., sulfites), certain drugs (e.g., aspirin), perfumes, or strong odors are precipitants for some patients. There is also evidence to suggest that changes in the social and physical environment of a child such as moving to a new home, going on vacation, or alterations in work or study space can precipitate asthma symptoms (10). How much and how these changes function to produce a physiologic response is not clear.

Allergy has a significant role in the pathophysiology of asthma. Studies from the United States, Europe, Australia, and New Zealand have established that IgE-mediated sensitization to indoor allergens (dust mite, cockroach, cat, dog) is a major risk factor for asthma and asthma exacerbation (18–24). Because persistent exposure to allergens and irritants (e.g., tobacco smoke) induces airway inflammation and hyperreactivity, environmental control is viewed as a therapy to reduce or prevent asthma symptoms (25). For purposes of discussion, it is useful to categorize environmental precipitants of asthma symptoms as those related to the physical environment

(indoor and outdoor) and social environment, although interactions of factors in each category occur.

Precipitants asthma symptoms in the indoor physical environment. DUST MITE. Studies of the effects of dust mite allergen presence in asthma are numerous. House dust mites are found in the dust of all homes built in temperate climates (26). In addition to being a major precipitant of attacks in children sensitive to the allergen, there is evidence that exposure to dust mite allergen, particularly in infants, may be an important factor in inducing the onset of asthma itself (18). The degree of symptom response to dust mite in sensitive children correlates with the extent of exposure (21). The primary sources of dust mites are beds, carpets, stuffed animals, upholstered furniture, and other soft furnishings. The usual approaches recommended for control are encasing mattresses with a covering impermeable to mite allergen, washing bedding in very hot water (over 55°C) and removing offending materials. These approaches significantly reduce asthma exacerbations (27). Studies of acaricide effectiveness in mite control have produced varying results (28,29), and the long-term success of using different media (benzyl benzoate, tannic acid) has been questioned. Dust mites are more prevalent in humid environments. Reducing mites by controlling indoor humidity is believed to be an effective means of control (10) and has been shown to have a positive effect on asthma symptoms (30).

COCKROACH. Up to 60% of children with asthma test positive to cockroach allergen (31). According to the NAEPP (10), cockroach allergen is the most common source of positive skin test reactions in inner-city populations. The expert panel guidelines recommend control through use of baits and traps to avoid irritating odors associated with chemical extermination, which itself may produce asthma symptoms. A factor complicating control is that cockroach allergen may be present when there is no visible sign of infestation (32). To date, there are no conclusive data to link interventions to control cockroach antigens to improvements in asthma symptoms (27).

ANIMAL DANDER. For some children, exposure to animal dander can cause symptoms of asthma. Dander can be found particularly in carpeting and upholstery exposed to the animal (33). Studies (33,34) have shown that animal allergens are transported on smaller particles than those that carry house dust mite allergen.

This means that dander allergens are likely to remain suspended in the air for an extended time, whereas mite allergen stays in the air only a few minutes. Air filtration systems may help with removal of airborne particles such as animal dander and tobacco smoke. However, they are not believed to be effective for allergens associated with heavy particles that rapidly fall out of the air, such as dust mite and cockroach allergens (10). Removal of the animal source has been associated with improvements in asthma symptoms but as a practical measure is often difficult to achieve (27).

TOBACCO SMOKE. Exposure to tobacco smoke is accepted as an important contributor to asthma prevalence and worsens asthma severity in both children and adults (10). It is associated with more frequent symptom exacerbations and increases in emergency department visits (35). The sole mode of control is to avoid inhaling environmental tobacco smoke.

For most patients, control of the environment is very difficult to achieve. Not all measures will be effective in reduction of asthma symptoms for a given child, as responsiveness to particular precipitants is highly individualistic. Some common activities thought to be remedial, such as vacuuming with a standard vacuum cleaner, can produce an increase in allergen-containing particles in the air and produce symptoms in children with specific allergic reactions. Further, general strategies for air quality control are questionable in terms of effectiveness of reducing symptoms, such as maintaining clean heating, ventilation, and air conditioning ducts. These measures will not affect house dust mite allergen and no studies have demonstrated as yet their effect on reduction of animal dander. In short, control of indoor environmental precipitants depends on the type of allergen in question.

There are other potential contributors to asthma exacerbations related to home and building construction. Tight housing providing little ventilation, and use of offensive building materials that emit volatile organic chemicals (VOCs) and formaldehyde have been discussed as influential in triggering asthma symptoms; these speculations, however, have not been empirically demonstrated.

Precipitants of asthma symptoms in the outdoor environment. Studies illustrating a causal effect between outdoor air pollution and prevalence of asthma are scant and, in fact, the increase in the prevalence

of the disease in developed countries over the last two decades has occurred at the same time as general improvements in outdoor air quality (21). On the other hand, studies have illustrated the deleterious effect of air pollution on patients who have active symptoms of disease. For example, decreased pulmonary function has been associated with exposure to particulates (36), and increases in bronchial hyperresponsiveness with exposure to smoke, SO₂, and NO₂ (37–39).

Increased ambient air pollution levels, particularly of respirable particulates (40), ozone (41), and SO₂ (42) reportedly precipitate asthma symptoms. With respect to particulate effects, studies in the United States and Europe report an association between increased morbidity and mortality and ambient particulate matter (PM) concentrations at PM levels currently below the U.S. National Ambient Air Quality Standards (43,44). It is believed that fine fraction particulate matter (< 2.5 µm) (PM_{2.5}) may be responsible for cardiopulmonary effects observed (45). Exposure to PM and co-pollutants in the ambient environment also has been posed as an explanation for increased morbidity and mortality in urban centers (46). Together, these studies suggest that air pollution is a complex mixture that likely produces effects that are important to the control of asthma. For example, in studies of the temporal relationship between air pollution and acute illness leading to mortality or hospital admissions, the relative risks associated with realistic increases in air pollution levels are small (47). Nonetheless, the number of people affected in a large population studied over a long period of time can be significant, and some groups (e.g., the elderly and children with asthma) may be particularly vulnerable.

Making the picture more complex is the possibility that levels of some outdoor air pollutants may influence indoor concentrations of particulate pollutants (26). One study (48) showed a significant association between indoor particulate matter and levels of outdoor particulates from traffic emissions. To add to the problem, the relative clinical importance of individual and combined elements of air quality to asthma has not been demonstrated. Such demonstration will not be easy, as research separating the impact of one form of pollutant from other forms in the air is difficult to conduct (49,50).

Sensitivity to fungus and mold is of concern in asthma. The outdoor fungus

Alternaria has been identified as a risk factor for developing the disease in childhood (51). Mold allergy seems to be more significant in children with asthma, depending on their geographic location (52), and has been implicated in severe and life-threatening asthma exacerbations (53,54). Being sensitive to outdoor pollens carries less risk for asthma (55), although grass and ragweed pollen exposure has been associated with the disease (56).

Control in the case of outdoor precipitants is usually in the form of recommending that patients curtail exercising during days of high atmospheric pollution, as increased respiration will increase the amount of exposure. Remaining indoors may decrease exposure, depending on the type of pollution in the air and ventilation available in the building (21). Although eliminating a precipitant such as *Alternaria* at its source may be virtually impossible, for others (e.g., smoke, particulates), prevention through regulatory means may be possible.

Two points seem evident regarding environmental precipitants of asthma. First, additional research is needed to identify the independent and combined, direct and indirect effects of indoor and outdoor air quality factors on the disease. Second, the effectiveness of various environmental control interventions to reduce asthma prevalence and symptom exacerbations must be tested.

Precipitants in the social environment including psychosocial factors. As with most diseases, it appears that stress can make asthma control more difficult. The extent to which it is a direct precipitant of wheezing and other asthma symptoms has not been noted. However, clinical recommendations and asthma self-management programs routinely counsel families to help children reduce their levels of stress both generally and during symptom exacerbations. Although little research has explored the idea, researchers have hypothesized that social environmental stresses of urban inner-city living, such as lack of supportive relationships, lack of community resources, violence, and economic worries are psychosocial risk factors for greater asthma-related problems among children living in these communities (57–59). Increased crime, noise pollution, and lack of safe transportation also have been suggested as aspects of the inner city that have a deleterious effect on day-to-day life. Such risk factors may operate directly on a child's health or, by increasing family stress, can indirectly affect efforts to manage the child's asthma (59,60).

Community-Wide Control Comprehensive Efforts Are Needed

For asthma, a ubiquitous disease for which there is no cure and no clear cut preventive or therapeutic answer, a comprehensive approach to control is needed that involves all the parties directly or indirectly affected by the disease. Once the right medical regimen for a particular child is prescribed, 90% of day-to-day clinical control of asthma is in the hands of patients and their parents. However, the family obviously cannot exert control over all the factors that can exacerbate the disease and needs assistance in a variety of ways. Until underlying causes are known and prevented, the patient's efforts to self-manage must be at the center of concerted activities at multiple levels of endeavor in order to control the disease. Figure 1 offers a picture of the concentric circles of influence and relationship that are necessary for asthma control. This perspective is consistent with a social-ecologic framework that recognizes that individuals are embedded within psychosocial, social, political, and economic systems that shape behaviors and health status (61). This approach suggests that interventions aimed at changing an individual's behavior must consider social relationships and resulting influences (such as family, clinicians, school personnel, classmates, neighbors) as well as the physical influences (e.g., location of household near high levels of ambient air pollution) in the individual's life. Additionally, interventions must consider how individuals modify their surroundings through individual and collective actions aimed at changing influences in the multiple rings of the concentric circles.

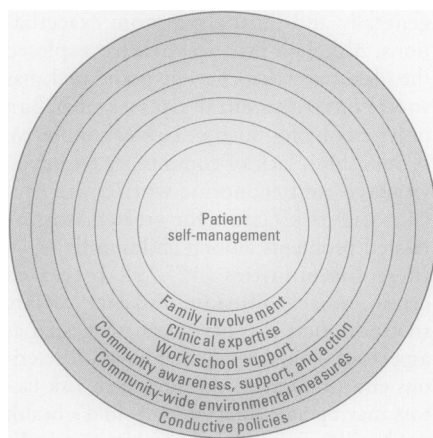


Figure 1. Concentric circles of influence in asthma control.

Patient and Family Self-Management

Self-management in asthma has been carefully distinguished in practice and research from self-treatment. In such a complex chronic disease, a partnership between patient and clinician is necessary to establish and maintain over time the correct therapeutic regimen for control. Self-management in asthma refers to the activities that the patient and family undertake on their own with guidance and instruction from the clinician.

A number of studies over the past 15 years (62,63) have demonstrated the importance of asthma self-management to disease control when control is defined as fewer symptom episodes and less health service use. Several of these studies involve programs in which the child, the parent, or both are trained to undertake measures to reduce and handle the onset of symptoms. The self-management programs have focused on managing asthma symptoms, preventing attacks, and developing communication among family members and between family and clinician. These interventions often include environmental control and special efforts to remove or avoid suspected irritants (e.g., tobacco smoke) and allergens (i.e., reduce exposure to dust mites and cockroaches, and avoid animal dander) if these give rise to symptoms.

Evaluation designs have precluded determination of which educational elements (use of medicine, environmental control, enhanced management of symptoms, etc.) are responsible for observed outcomes. However, these comprehensive programs to improve self-management have been highly successful in reducing episodes of symptoms, improving school performance, enhancing psychological well-being, and decreasing hospital and emergency department use. Table 1 (64–81) provides a summary of these asthma intervention studies and evaluation results.

Role of the Clinician

It is estimated that 80–90% of children with asthma see general practice physicians for their care and an additional 10–20% are seen by pulmonologists or allergists. A range of other clinicians (e.g., nurses, respiratory therapists) see patients who use hospital and clinical services. However, these estimates do not account for the fact that large numbers of children, primarily in low income, racial/ethnic minority communities, do not receive regular care for the disease.

Efforts to reach clinicians have been undertaken by professional associations and the NAEPP, but it is accepted that the recommendations in the "Guidelines for Diagnosis and Treatment of Asthma" (10) are not followed in an optimum way by health professionals (82). Enhancing clinical practice is essential to control. Although there are very few rigorously evaluated programs for changing clinician behavior in asthma where outcomes for children have been assessed, two studies are worth noting. Both have been based on the idea that the clinician must not only understand effective therapeutic regimens for asthma but also must be able to communicate about the disease in such a way that patient self-management, including efforts to control factors in the physical environment, is optimized. These studies have demonstrated positive results regarding improved clinician prescribing and counseling practices (35,83). One study (83) has shown reductions in health care use when patients see physicians trained to treat and communicate in the recommended way.

Influence of the Social and Physical Environment of the School

Literature over the years has shown a general lack of understanding of asthma treatment by school personnel and classmates of children with asthma (84). How to treat emergencies and how to support self-management of children with the disease are unresolved issues in many schools. In communities where there are no school physicians or nurses, providing adequate self-management support is almost always a concern. At least two studies (35,85) have shown that providing asthma self-management education to children during school time can significantly reduce the child's symptoms, improve psychological adjustment, and enhance school performance. However, the independent effect of increasing the information and skills of principals, teachers, and classmates on the child's ability to manage asthma has not been evaluated.

Further, to date no rigorous study has been undertaken to assess the impact of modifications in the school's physical environment on the health of children with asthma. It is believed that the physical environment of the school may pose a threat to the health of these children. For example, high levels of humidity may contribute to dust mite proliferation; air intakes may bring in gases, fumes, or odors; strong chemicals may be used for cleaning; cockroach antigen

Table 1. Outcomes of evaluated pediatric asthma education.

Study	<i>n</i>	Evaluation design	Follow-up period	Outcomes
Staudenmayer et al. (64)	40	Pre/post	6 months	Change in direction of fewer school absences ($p = 0.09$) Reduced number of emergency physician visits for those with baseline use ($p = 0.03$) Reduced hospitalizations ($p = 0.03$)
Fireman et al. (65)	26	RCT	6–16 months	Decreased school absences ($p < 0.05$) Reduced ED use (no statistical analysis) Reduced hospitalization time (no statistical analysis)
Clark et al. (66)	310	RCT	1 year	Improved academic performance ($p = 0.05$) Increased self-management behavior: parent ($p = 0.0001$); child ($p = 0.05$) No difference in school absences Reduced ED use among those with baseline use ($p = 0.05$) Reduced hospitalizations among those with baseline use ($p = 0.05$)
Lewis et al. (67)	76	RCT	1 year	Reduced ED visits ($p < 0.001$) Reduced number of hospital days ($p < 0.01$)
Hindi-Alexander and Cropp (68)	92	Pre/post	1 year	Reduced school absences ($p < 0.005$) Reduced ED use but not statistically significant No difference in hospitalizations
McNabb et al. (69)	14	Pre/post	1 year	Reduced ED use (no statistical analysis)
Rubin et al. (70)	54	RCT	1 year	No difference in school absences Improvement in ED use but not statistically significant
LeBaron et al. (71)	31	RCT	4 months	Increased knowledge about cromolyn (no statistical analysis) No change in pulmonary function or systems
Wilson and Starr-Schneidkraut (72)	80	RCT	1 year	Increased symptom free days ($p = 0.004$) Fewer nights of parental sleep interruption
Mesters et al. (73)	67	RCT	1 year	Higher level of asthma self-efficacy ($p < 0.02$) Increased self-management behavior ($p < 0.01$) Decreased physician visits ($p < 0.01$)
Rakos et al. (74)	43	RCT	1 year	No significant difference in school absences No significant differences in ED use or emergency physician visits
Mitchell et al. (75)	368	RCT	6 months	Differences according to ethnicity of child no differences in hospital days
McIntosh et al. (76)	92	RCT	4–6 months	More treatment (35%) than control (17%) subjects reported smoking outside their homes at post test (and their children's cotinine levels were lower) but not statistically significant
Jenkinson et al. (77)	177	RCT	3 and 12 months	Significant knowledge increases ($p = 0.002$) No other significant change
Parcel et al. (78)	104	Comparison group	1 year	Improved ED use but not significantly significant Higher levels of self-efficacy regarding asthma ($p = 0.018$)
Evans et al. (79)	239	RCT	1 year	Increased self-management ($p = 0.05$) Increased communication with parent ($p = 0.002$) Better academic grades ($p = 0.05$) Fewer days with symptoms ($p = 0.004$)
Hughes et al. (80)	95	RCT	1 year	Reduced school absences ($p = 0.04$)
Robinson (81)	74	Pre/post	3 years	Reduced school absences (no statistical analysis) Better MDI technique (0.0005) Fewer hospital days (0.02)

Abbreviations: ED, emergency department; MDI, meter dose inhaler; pre, before intervention test; post, after intervention test; RCT, random controlled trial.

or animal dander may be present; chalk dust may be prevalent; and offending pesticides may be employed.

Community Awareness, Support, and Action

Some surveys and extensive clinical experience have led to the conclusion that many asthma patients do not know the benchmarks of successful asthma treatment and therefore live with a lower level of functioning than should be accepted. As a result, a number of national organizations

have produced educational materials designed to help patients and the public recognize the goals of care, i.e., the child with asthma should be able to sleep through the night, participate in normal physical activity without exacerbations and be symptom free. Public understanding of the extent of asthma prevalence, the objectives of treatment, and the ways to foster self-management so that patients receive adequate support for their management efforts is seen as an important route to asthma control.

For children with asthma, control requires knowledge of the principles of self-management as well as support from family, friends, and neighbors with whom the children, their parents, and caregivers interact on a regular basis. Community-level interventions can help to provide that support in different ways. In one study focusing on improving clinical care (86), a community-wide campaign was successfully employed to achieve better coordination of asthma clinical services. Another study focusing on asthma among residents

of low-income neighborhoods in St. Louis, Missouri (87), showed that mobilizing community residents and organizations on behalf of asthma control had positive effects. This project undertook an information campaign and also trained community residents to counsel patients with asthma and refer them for service. Introduction of the neighborhood workers significantly increased the number of asthma patients who were informed about their disease and sought appropriate care.

Currently, there are more than 45 active community coalitions in the United States for asthma control. These coalitions are primarily partnerships of patient, provider, and community organizations in the public, private, and voluntary sectors seeking to coordinate their efforts and to increase public awareness of asthma control activities (88).

An intervention that has not yet been explored is use of a community organizing approach to reduce psychosocial stressors at the neighborhood level. Given the previously mentioned hypothesized relationship between stressors in the urban inner-city environment and the increase in asthma in urban areas, a neighborhood intervention that targets more general psychosocial stressors such as crime, violence, noise pollution, and lack of community resources may help in asthma control.

Community-Wide Control of Environmental Influences

Although patients sensitive to indoor environmental precipitants can do much to reduce some of these triggers to symptoms (e.g., dust mites, cockroach, dander, tobacco smoke), not all remedies are within their total control. Neighborhood or community-wide strategies may be required. Further, the quality of outdoor air is certainly beyond the control of an individual family. Some effective remedies for air pollution may be accomplished by legal or regulatory intervention. To effect macro-level control measures, a combination of community organization and policy change strategies will be needed. Most important, interventions designed to reach across communities and even nations must be based on sound scientific evidence. More research is needed to fill the wide gaps in our current knowledge of environmental influences.

The Role of Public and Institutional Policy

The final ring of the concentric circles shown in Figure 1 represents policies conducive to asthma control. In certain

areas of policy the answers seem clear-cut. For example, in some American states children are not allowed to carry their asthma medicines with them at school. In other parts of the United States, explicit policies of the state department of education and/or health ensure children access to these medicines during the school day, and this is a trend to be encouraged. Yet another example is the availability of school nurses in some school districts to see children with asthma. Again, this is a policy that may assist families to manage asthma better.

But other areas are less clear. Can and should certain standards of environmental control (e.g., cleanliness of school facilities, levels of acceptable exposure to diesel exhaust particulate, levels of acceptability for building construction) be tied to expected improvements in asthma? What types of policy changes are appropriate and effective? Considerable research is needed to address these questions. Further, it is accepted that access to sufficient clinical care is central to asthma control. Increased morbidity and mortality, especially in low-income families, has been tied to inadequate medical care (89). National, state, and community-wide policies for ensuring availability of appropriate and effective treatment, including reasonable access to general and specialized services, is fundamental to control.

Projects of the Michigan Center for the Environment and Children's Health

Based on the research evidence and conceptual framework described above, in an effort to control asthma in school-age children in low-income neighborhoods of Detroit, Michigan, the Michigan Center for the Environment and Children's Health (MCECH) has mounted three studies. MCECH is a collaborative research initiative funded by the U.S. Environmental Protection Agency and the National Institute of Environmental Health Sciences and based at the University of Michigan School of Public Health. An important feature of MCECH is the local partnership between university researchers, health agencies, and community-based organizations in which all three constituent bodies jointly decide the research questions, design, and methods for the center's projects. The center is an outgrowth of the work of an ongoing community health agency—University of Michigan partnership, the Detroit Community-Academic Urban Research Center, funded in 1995 by the Centers for Disease Control and Prevention (90,91).

The work of MCECH is guided by a set of community-based research principles (91) that specify a participatory, collaborative approach to research. All parties are actively involved in the research process aimed at integrating knowledge and action for mutual benefit of all partners (92). By using this partnership approach, MCECH's efforts are consistent with the call among health researchers for greater community involvement in research and interventions (60,93,94) in order to better identify and address the complex issues that compromise the health of people living in marginalized communities (95–97). The overall goals of the three core MCECH research projects are to identify features of the underlying inflammation associated with asthma, to monitor the effects of air quality on asthma exacerbations, and to build the capacity of children and their families to reduce precipitants of symptoms. The studies (briefly described below) are organized to attend to the associations and relationships of influence depicted in Figure 1. They are guided by steering committees composed of representatives from the partner organizations involved.

The Pathogenesis of Asthma

Although studies have confirmed that asthma symptoms are precipitated by exposure to cockroach allergen, mediators within the lung that dictate the progression of disease have not yet been fully defined. Targeted pharmacologic therapy has the potential to improve the treatment of asthma by addressing those mediators directly responsible for exacerbations. This MCECH project is testing the hypothesis that asthmalike pulmonary injury is mediated by the local production of chemokines. Chemokines are small molecular weight peptides that induce the chemotaxis and recruitment of inflammatory cells. They are powerful mediators with long-lasting and potent biologic activities. This study examines the acute and chronic pulmonary inflammation that develops after direct injection of the chemokines into the lung. The assessment of the injury includes histologic and morphometric analysis as well as an assessment of the innervation of the airways. The project also involves the development of a mouse model of asthmalike pulmonary inflammation in response to cockroach allergen. This model was developed by locating households with high levels of cockroach allergen and using this material to immunize the mice. The mice are challenged by exposure to aerosols

containing the allergen-bearing dust and the pulmonary injury is carefully quantified. An important related activity is investigation of the biochemical pathways responsible for the upregulation of chemokines in cells sensitized and then challenged with cockroach allergen. Reactive oxygen and reactive nitrogen intermediates are of particular interest, as they increase the transcription of chemokines. Finally, the project is testing the central hypothesis that chemokines are important in the pathogenesis of asthma. This test entails blocking the biologic activity of the chemokines with specific neutralizing antibodies and determining if there is a reduction in the pulmonary inflammation induced by repeated exposures to cockroach allergen. Successful completion of the project will help to both delineate the underlying inflammatory mechanisms of disease and identify potential novel targets for intervention.

Exposure to Indoor and Outdoor Air

National trends in the increase in asthma are especially visible in inner-city Detroit. This research is contributing to the identification of combinations of factors that precipitate asthma symptoms. First, the prevalence of asthma among the elementary school-age children in two distinct racial/ethnic minority urban populations (African American, Hispanic) in Detroit is being determined. Approximately 7,000 students attending elementary schools in the two areas of Detroit where MCECH community partner organizations are located are invited to participate in the first phase of the research. The child's parent completes a short screening questionnaire for asthma, and those with diagnosed and suspected asthma are enrolled in the second phase of the study. Through home visits and monitoring, the presence of components of the ambient air and of indoor air contaminants is determined. Family and neighborhood characteristics (e.g., stressors) associated with increased risk for asthma are also identified. Subsequently, data regarding seasonal and daily fluctuations in ambient air pollution and indoor air contaminants are analyzed for their association with changes in children's asthma symptoms. In addition, relationships between exposures to environmental factors and physical activity patterns of children with asthma are assessed. Findings from this project will enhance understanding of the effects of individual and combined environmental precipitants on asthma exacerbations and on activity limitations of children.

A Community-Based Intervention to Reduce Environmental Precipitants

This project is seeking an effective way to reduce exposure of children to negative environmental factors at home and within their neighborhoods. The homes of children with asthma who are enrolled in the study described above are being visited over a 2-year period (nine visits in the intensive first year, three visits in the second year) by trained community environmental specialists. These outreach workers work with the family to share information on asthma self-management and environmental triggers and to reduce indoor environmental factors such as cockroach allergen, cat dander, and environmental tobacco smoke. In the second year of the intervention project, this household intervention is combined with a neighborhood-level intervention designed to mobilize community residents and organizations to support families in their efforts to exert environmental control and reduce neighborhood-level psychosocial stressors. Combinations of these two interventions of varying lengths of time and intensity are being tested in conjunction with the data collected in the exposure study. When completed, the study will shed light on the effectiveness of household and community-level interventions in changing family and community environmental control behavior and the symptom status of children with asthma.

To mount effective and comprehensive approaches to control and to identify means to prevent childhood asthma, significant additional environmentally focused community-based research will be needed of the types being undertaken by MCECH and other centers around the country. The concentric circles of association necessary for asthma control presented here (Figure 1), provide a useful framework for conducting this research.

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